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(71) Applicant
National Semiconductor Corporation,

(Incorporated in USA-California),

2900 Semiconductor Drive, Santa Clara, State of California 95051, United States of America

(72) Inventor
Hem P. Takiar

(74) Agent and/or Address for Service
Boult, Wade & Tennant, 27 Furnival Street, London EC4A 1PQ

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EP A2 0034785

(58) Field of search
H1K
Selected US specifications from IPC sub-class H01L

(54) Oxidation inhibition of copper bonding pads using palladium

(57) A copper bonding pad structure for the tape automated bonding of semiconductor devices includes a palladium anti-oxidation layer 30 over the exposed copper. The palladium layer has a thickness in the range from about 80 to 300 Angstroms, and is particularly suitable for use since it has a very low diffusivity into copper, even at elevated temperatures. In the preferred embodiment, the copper bonding pad structure comprises an aluminium layer applied directly over an aluminium metallization pad 12, a nickel layer 22 applied directly over the aluminium layer, and an overlying copper layer 24. The nickel layer inhibits the migration of copper into the aluminium, while the copper layer with palladium may be bonded directly to copper bump tape. In an alternative embodiment, a copper bump is formed directly over the copper bonding pad, which allows for bonding to a flat copper bonding tape.

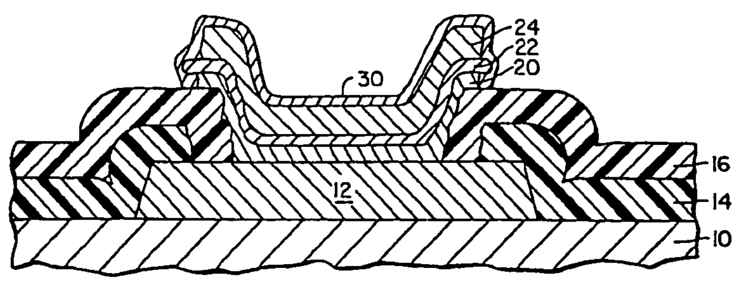

FIG._7.

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The drawing(s) originally filed was (were) informal and the print here reproduced is taken from a later filed formal copy.

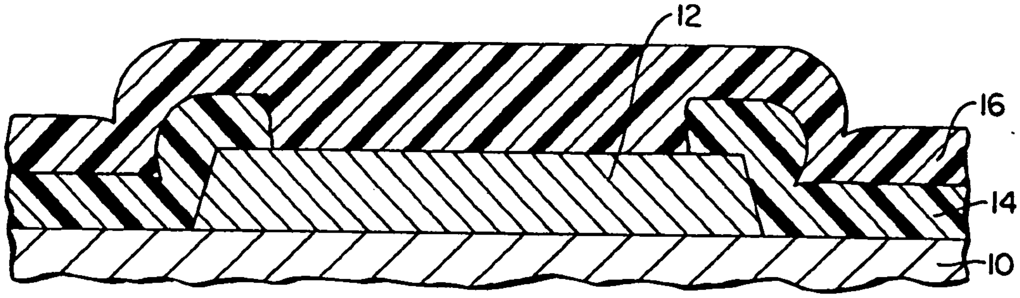

FIG._1.

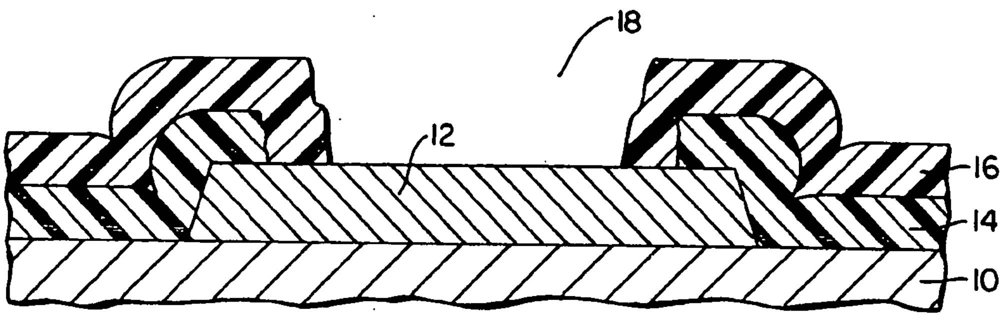

FIG._2.

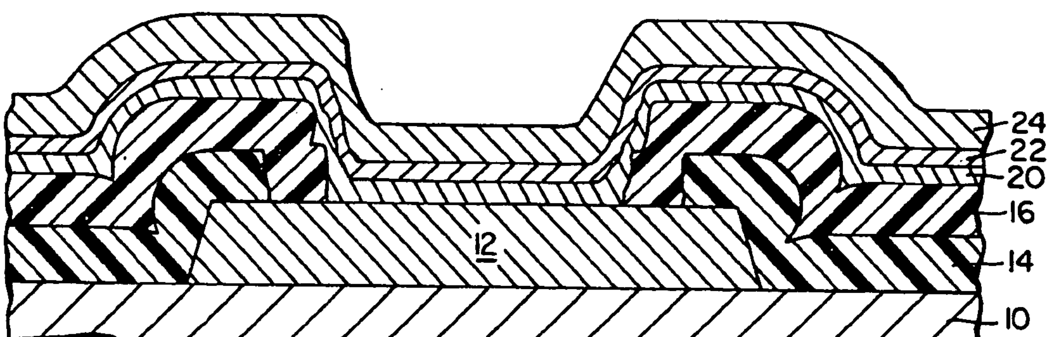

FIG._3.

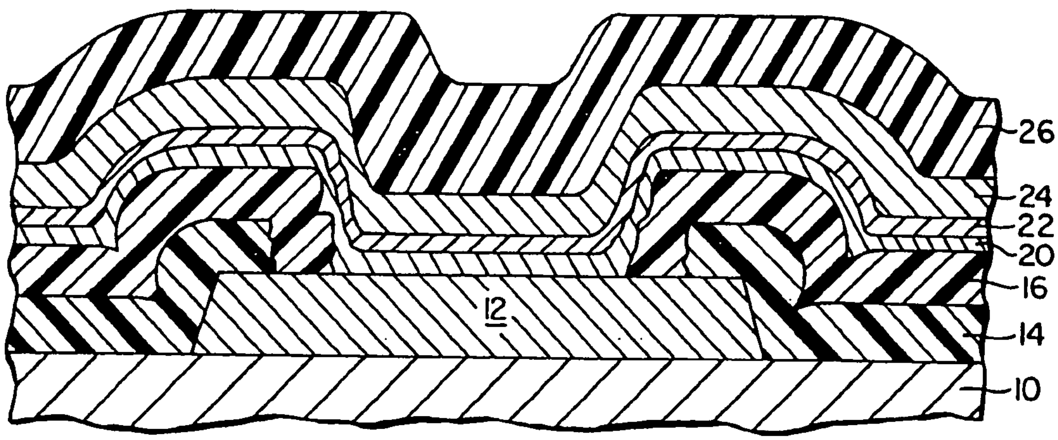

FIG._4.

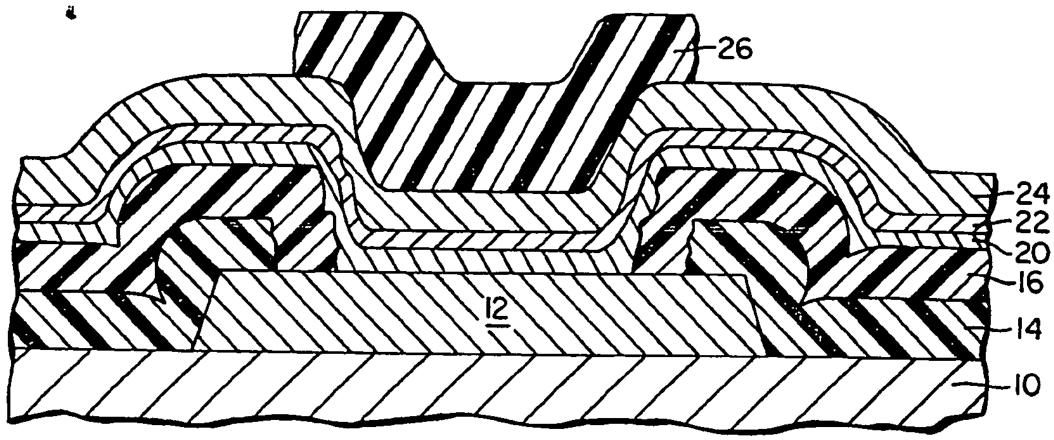

FIG._5.

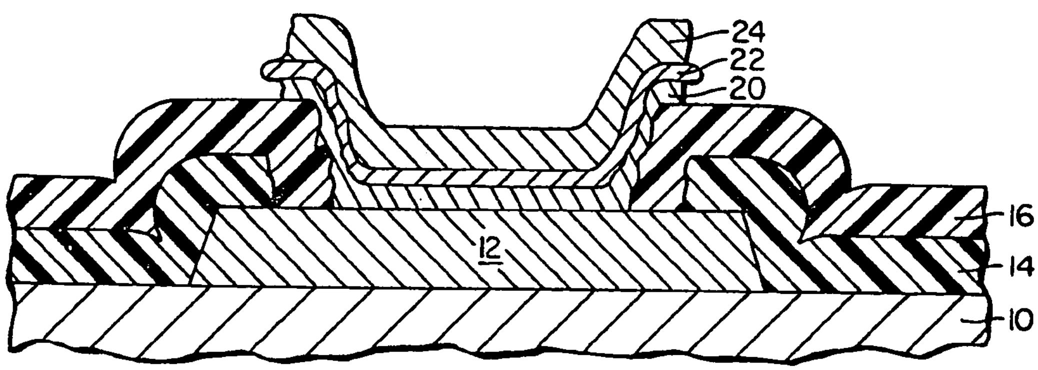

FIG._6.

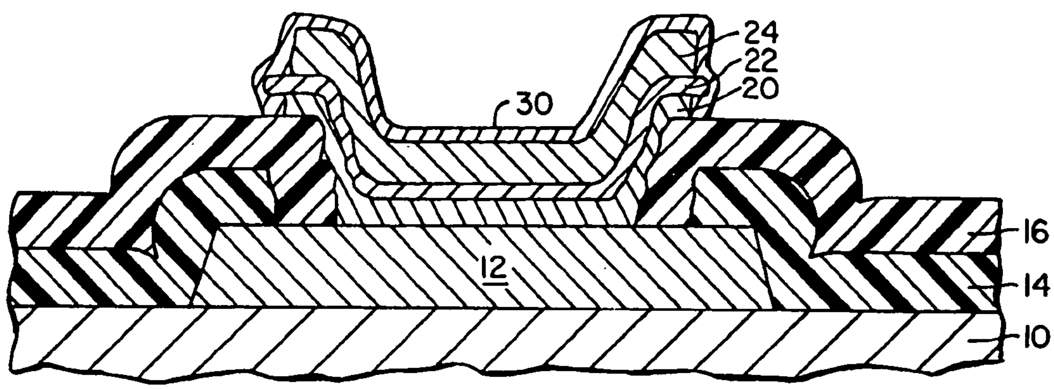

FIG._7.

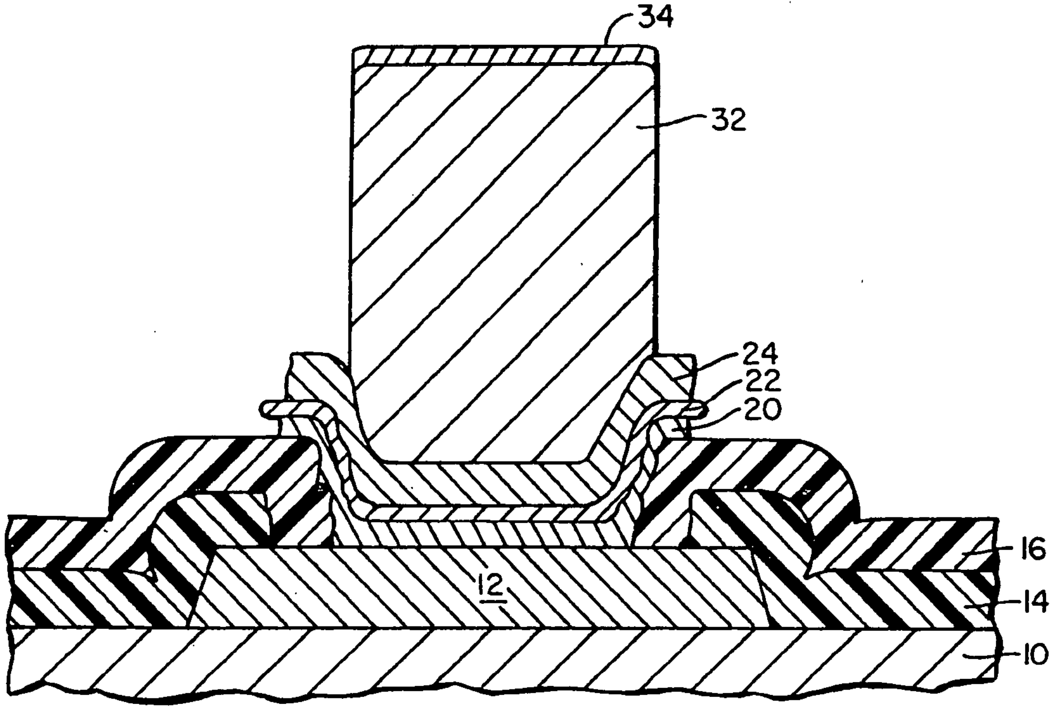

FIG._8.

SPECIFICATION

Oxidation inhibition of copper bonding pads using palladium

Background of the invention

1. Field of the invention

The present invention relates generally to tape automated bonding between copper bonding pads on semiconductor devices and lead frames or other external circuitry. More particularly, the invention relates to oxidation inhibition on the copper bonding pads.

Tape automated bonding is a method for simultaneously connecting a plurality of bonding pads on a semiconductor device to external circuitry, typically by connection to leads on a lead frame on which the device is to be mounted. The bonding pads are usually formed from copper and define the input and output terminals of the semiconductor device.

Tape automated bonding is accomplished using a metal tape, typically a thin copper tape or plated copper tape, having short connector beams formed therein. By aligning the tape with the semiconductor device, the inner ends of the connector beams may be bonded to the bonding pads on the semiconductor device in a single operation, typically thermal compression or reflow, to form inner lead bonds. After the inner lead bonds are formed, outer lead bonds between the outer ends of the connector beams and the lead frame leads are formed and the excess tape excised.

In forming the inner lead bonds, it is necessary that a projection or bump be formed on one of either the connector beams or the bonding pad. Such bump serves to provide the metal necessary for forming the bond as well as for providing the necessary distance or offset between the connector beam and the semiconductor die. In either case, it is necessary that the copper bonding pad or bumped copper bonding pad be treated to inhibit oxidation of the copper, which oxidation would interfere with the bond quality and the resulting electrical contact with the connector beam.

Heretofore, oxidation of the copper bonding pad or bumped copper bonding pad has been accomplished by depositing a thin layer of gold over the top layer of the semiconductor device, typically by sputtering or using an electroless gold plating bath. The gold layer was usually thin, having a thickness of about 500 Å, and the inner leads were formed in a conventional manner using either bumped copper tape or flat copper tape.

While the use of gold to inhibit the oxidation of copper is generally acceptable, it suffers from certain drawbacks. In particular, when exposed to higher temperatures, the gold will diffuse into the underlying copper, leaving the copper exposed to oxidation. Such diffusion requires the use of thicker gold layers to adequately protect the underlying copper, and in some cases diminishes the ability of the gold layer to protect the copper against oxidation.

For these reasons, it would be highly desirable to provide alternate methods for protecting copper bonding pads and copper bumped bonding pads against oxidation. In particular, it would be desirable to identify other protective coating materials which are electrically conductive, which are non-reactive in the environments likely to be encountered by the semiconductor, which display low diffusivity in copper, into which copper displays a low diffusivity, and which may be conveniently applied to the surface of the semiconductor device.

2. Description of the background art

Tape automated bonding on semiconductor devices having bumped bonding structures is described generally in U.S. Patent 4,000,842. The tape automated bonding employing bumped bonding tape is described generally in U.S. Patent 4,209,355. The use of various znti-oxidation coatings, including gold, chromate, and copper phosphate, on copper bonding structures is described in U.S. Patent 4,188,438.

Summary of the invention

Improved methods for inhibiting the oxidation of copper bonding structures on semiconductor devices are provided. The copper bonding structures are of the type which are used for tape automated bonding of the semiconductor to a lead frame or other external circuitry. Specifically, the copper bonding structures form the inner lead bonds with the connector beams of the bonding tape. The process of the present invention is useful with both bumped bonding structures which are intended to mate with flat bonding tape, as well as with unbumped bonding structures which are intended to mate with bumped bonding tapes.

The method of the present invention comprises applying a layer of palladium as an oxidation inhibition layer over the copper bonding structures. Preferably, the palladium layer is applied to a thickness in the range from 80 to 300 Å, more preferably in the range from 100 to 200 Å. Such application is normally accomplished by sputter deposition. It has been found that palladium, in contrast to the gold oxidation inhibition layers of the prior art, displays a very low level of migration into the underlying copper layer, even at high temperatures. Moreover, copper resists migration into the palladium, even at the same high temperatures. The palladium has further been found not to interfere with the formation of low resistance electrical connections between the bonding tape and the bonding structure, and is substantially non-reactive under the conditions to which the semiconductor is normally exposed. In particular, the palladium is highly resistant to oxidation under high oxygen environments at elevated temperatures.

Brief description of the drawings

Figure 1 illustrates an aluminum metallization pad covered by a pair of insulating layers prior to formation of the copper bonding pad structure of the present invention.

Figure 2 illustrates the metallization pad of Figure 1 after a opening has been etched in the insulating layers to provide access to the metallization pad.

Figure 3 illustrates the exposed metallization pad of Figure 2 after aluminum, nickel and copper layers have been sequentially applied.

Figure 4 illustrates the metallization pad structure of Figure 3, further including a photoresist layer formed thereover.

Figure 5 illustrates the structure of Figure 4, wherein the photoresist layer has been exposed and developed to remove all areas other than those overlying the metallization pad.

Figure 6 illustrates the copper bonding pad structure of the present invention, which has been formed by etching the copper, nickel, and aluminum layers and stripping the photoresist.

Figure 7 illustrates the copper bonding pad structure of Figure 6 having a palladium layer applied thereover to inhibit oxidation of the copper.

Figure 8 illustrates an alternative embodiment of the present invention, where the copper bonding pad structure of Figure 6 has a copper bump structure formed thereover, further having a palladium layer to inhibit oxidation of the copper bump.

Description of the preferred embodiment

The present invention provides an improved copper bonding pad structure intended for tape automated bonding of semiconductor devices. The copper bonding pad structure is characterized by a final layer of palladium which acts to inhibit oxidation of the copper bonding pad structure, while at the same time allowing thermocompression bonding of the copper bonding pad structure to conventional copper bonding tape. The palladium layer is normally pure palladium, or an alloy consisting primarily of palladium, and is applied by sputter deposition or electroless plating at the final stages of the water fabrication.

In the preferred embodiment, the copper bonding structure is formed of three metal layers deposited sequentially over an exposed aluminum metallization pad, which structure prevents the migration of copper from the bonding pad into the underlying aluminum. Although this is the preferred embodiment, it will be appreciated that the present invention will be equally useful with other bonding pad structures which are presently known and which may be developed in the future. The present invention relates to the oxidation inhibition of the exposed copper on the copper bonding pad structure, and is not limited by the particular manner in which the copper is connected to the underlying circuit elements.

Referring now to Figures 1-8, the process for forming the copper bonding pad structures of the present invention will be described in detail. Figure 1 illustrates a semiconductor substrate 10 having an aluminum metallization pad 12 formed on its surface. Passivation layers 14 and 16 have been formed over the metallization pad 12, in a conventional manner. In order to form the copper bonding pad structure of the present invention, it is first necessary to provide an access opening through the insulating layers 14 and 16. This may be accomplished by conventional photolithographic techniques, to provide opening 18, as illustrated in Figure 2.

After formation of the opening 18, an aluminum layer 20 (Figure 3) may be formed directly over the aluminum metallization pad 12, as well as covering the insulating layer 16. The aluminum layer will typically have a thickness of at least 2,000 Å, more typically being in the range from 2,000 to 6,000 Å, usually being about 4,000 Å. Since the aluminum layer is being applied directly over the aluminum metallization pad 12, the aluminum layer may be applied by sputter deposition, evaporation, or other conventional technique.

After the aluminum layer 20 is deposited, a nickel layer 22 is deposited directly over the aluminum layer. The nickel layer 22 will be deposited by conventional methods, typically by sputter deposition, and will form a nickel-aluminum alloy at the interface between layers 20 and 22. The thickness of the nickel layer will be sufficient to prevent migration of the copper into the aluminum, usually being at least about 2,000 Å, more usually being in the range from 2,000 to 5,000 Å, usually being about 3,000 Å.

Copper layer 24 is next deposited by sputter deposition to a thickness of at least 4,000Å, usually in the range from about 4,000 to 15,000Å, more usually about 8,000Å. The copper layer serves to bond directly to the copper bumped tape in a conventional manner.

After applying the three metal layers 20, 22 and 24 of the metallization pad structure, a photoresist layer 26 (Figure 4) is applied over the semiconductor device. The photoresist will be used to define the limits of the metallization pad structure. First, the photoresist is exposed and developed so that the photoresist is removed from most of the area of the semiconductor device, but remains over the aluminum metallization pad 12, as illustrated in Figure 5. The copper and nickel layers 22 and 24, respectively, are then etched in a liquid etchant, such as nitric acid and hydrogen peroxide, followed by an aluminum etch in phosphoric/acetic acid mixture. The etches are continued until the metal layers are substantially removed from all areas of the semiconductor device except those areas above the metallization pad 12 which is protected by the photoresist cap 26a (Figure 5). Photoresist cap 26a is then removed, and the copper cleaned in a mild acid. The resulting structure is illustrated in Figure 6.

The structure illustrated in Figure 6 is generally suitable for thermocompression bonding to copper bonding tape. The exposed copper layer 24, however, is subject to oxidation when the semiconductor device is exposed to an oxygen-containing ambient. Such oxidation is undesirable since it interferes with the formation of a low resistance bond with the copper bonding tape.

Referring now to Figure 7, in a first embodiment of the present invention, oxidation of the copper bonding pad structure 24 is inhibited by the application of a thin palladium layer 30 on top of the

copper metallization layer 24. The palladium layer 30 is applied over the entire top surface of the semiconductor device by either sputter deposition of electroless plating. The palladium layer 30 is then removed from all areas of the wafer other than the bopper bonding pads 24 by conventional photolithographic masking techniques. Alternatively, the palladium layer could be applied by sputtering or evaporation to the structure in Figure 3. The excess palladium would then be removed during the subsequent etching operation described in connection with Figures 4-6.

In either case, the palladium will be applied to a final thickness in the range from 80 to 300 Å, more usually in the range from about 100 to 200 Å. It has been found that the palladium layers below about 80 Å often display discontinuities in the coverage of the copper, and are therefore less effective in inhibiting oxidation. In contrast, palladium layers having a thickness above about 300 Å are very brittle and tend to crack during the thermocompression bonding of the copper bonding tape. The palladium layer 30 will normally be applied by sputter deposition, although electroless plating may also find use.

Referring now to Figure 8, a second embodiment of the present invention is illustrated. A copper bump 32 is formed directly on top of the copper layer 24. The copper bump 32 is formed by conventional techniques, and will typically project about 0.001 inch above the surface of the semiconductor device. A palladium layer 34 is then applied over the copper bump by either of the techniques described in connection with Figure 7. As illustrated in Figure 8, the palladium layer 34, would have been applied to the structure of Figure 3, and subsequently etched with layers 20, 22, and 24, as the vertical surfaces of the palladium have been removed.

After the deposition of the palladium layer 30 or 34, the semiconductor devices are generally ready for the formation of inner lead bonds with the copper bonding tape by conventional techniques.

Although the foregoing invention has been described in some detail by way of illustration and example for purposes of clarity of understanding, it will be obvious that certain changes and modifications may be practiced within the scope of the appended claims.

CLAIMS

1. A semiconductor device having at least one copper bonding pad structure, wherein said copper bonding pad is covered by a layer of palladium to inhibit oxidation of the underlying copper.

2. A semiconductor device according to claim 1, wherein the layer of palladium has a thickness in the range from about 80 to 300 Angstroms.

3. A semiconductor device having at least one metallization pad structure comprising an aluminium metallization pad, an aluminium layer deposited directly over the aluminium metallization pad, a nickel layer deposited directly over the aluminium layer to form a stable aluminium-nickel alloy at the interface, a copper layer deposited over the nickel layer to allow bonding to copper bonding tape, and a palladium layer deposited over the copper layer to inhibit oxidation of the underlying copper.

4. A semiconductor device according to claim 3, wherein the aluminium layer has a thickness in the range from about 2,000 Angstroms to 6,000 Angstroms.

5. A semiconductor device according to claim 3 or claim 4, wherein the nickel layer has a thickness in the range from about 2,000 Angstroms to 5,000 Angstroms.

6. A semiconductor device according to any of claims 3 to 5, wherein the copper layer has a thickness in the range from about 4,000 Angstroms to 15,000 Angstroms.

7. A semiconductor device according to any of claims 3 to 6, wherein the palladium layer has a thickness in the range from about 80 to 300 Angstroms.

8. A semiconductor device according to any foregoing claim, wherein the copper layer is bumped.

9. A semiconductor device according to any foregoing claim, wherein the copper layer is not bumped.

10. A method of forming a copper bonding structure on an aluminium metallization pad, said structure being capable of bonding to copper tape, said method comprising: applying an aluminium layer directly over the aluminium metallization pad; applying a nickel layer directly over the aluminium layer; applying a copper layer directly over the nickel layer; and applying a palladium layer over the copper layer to inhibit oxidation of the copper.

11. A method according to claim 10, wherein the aluminium layer is applied to a thickness in the range from about 2,000 Angstroms to 6,000 Angstroms.

12. A method according to claim 10 or claim 11, wherein the nickel layer is applied to a thickness in the range from about 2,000 Angstroms to 5,000 Angstroms.

13. A method according to any of claims 10 to 12, wherein the copper layer is applied to a thickness in the range from about 4,000 Angstroms to 15,000 Angstroms.

14. A method according to any of claims 10 to 13, further comprising applying a copper bump over the copper layer before the palladium has been deposited.

15. A method of forming a copper bonding structure on a semiconductor device for thermocompression bonding to copper tape, said method being characterised by applying a layer of palladium over the copper bonding structure to inhibit oxidation of the copper.

16. A method according to any of claims 10 to 15, wherein the palladium layer is applied to a thickness in the range from 80 to 300 Angstroms.

17. A method according to any of claims 10 to 16, wherein the palladium layer is applied by sputter deposition or electroless plating.

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